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VEGETAL DEVELOPMENT FOLLOWING PRESCRIBED BURNING OF DOUGLAS-FIR IN SOUTH-CENTRAL IDAHO

by L. Jack Lyon

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INTERMOUNTAIN FOREST AND RANGE
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THE AUTHOR

L. Jack Lyon, Wildlife Research Biologist, has been leader of the research work unit devoted to ecology and management of wildlife habitat since 1962. This unit is headquartered at the Forestry Sciences Laboratory on the campus of the University of Montana. From 1955 to 1961, Dr. Lyon was a Research Biologist for the Colorado Game and Fish Department. His studies in postfire forest succession are widely recognized as a unique and continuing contribution to the understanding of seral vegetation dynamics. Consequently, he is a recognized authority on ecological succession and wildlife-vegetation relations of forest habitats. Dr. Lyon holds both a B.S. and an M.S. degree in Wildlife Management from Colorado State University, as well as his Ph.D. degree in the same field from the University of Michigan. He has authored over 25 technical publications and articles. He is a life member of the Wildlife Society and a member of the American Institute of Biological Sciences, American Association for the Advancement of Science, and Ecological Society of America.

ABSTRACT

One-hundred and twenty acres of standing Douglas-fir timber in Neal Canyon, near Ketchum, Idaho, were burned with prescribed fire on August 1, 1963. This paper presents descriptions of the fire, the prefire forest community, and the first 7 years of postfire vegetal development. Effects on wildlife habitat are stressed.

The Neal Canyon prescribed fire was burned during daylight hours under conditions severe enough to produce crown fire in the timber. Measurements of heat flux were comparable to measurements taken in slash fires with 15 to 20 tons of fuel per acre and fine fuel moisture near 5 percent. All litter and herbaceous plants, all dead woody stems under 3 inches in diameter, and all live stems under 2 inches were completely consumed.

After seven growing seasons, the early seral herbaceous community contains nearly twice as many species as the preburn community. Virtually all the perennial herbaceous species resprouted and many new species have appeared. Postfire canopy cover has never dropped significantly below preburn levels.

The Douglas-fir overstory was killed in the fire, but a new forest has been established by planting, direct seeding, and some natural seeding. Canopy closure of the tree overstory is predicted before the thirtieth year.

Most of the shrub species recorded in the community before the fire have resprouted, but the relative importance of several species has been significantly modified. Crown volume per acre of Rocky Mountain maple *(Acer glabrum)* was greater than all other shrub species before the fire. During the first 7 postfire years, however, Scouler willow *(Salix scouleriana)* and maple have been about equal in crown volume, and it is predicted that crown volume per acre of snowbrush *(Ceanothus velutinus)* will surpass all other shrub species by succession year 9.

The Neal Canyon prescribed fire was judged to be successful in all respects. Silvicultural objectives were achieved, wildlife habitat was significantly improved, and there was no apparent watershed damage. A theoretical model is presented to show that the preburn forest community description can be used to predict postfire community structure and long-term development pattern.

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Figure 1. — Main study site, Neal Canyon prescribed fire area, July 1963.

Neal Canyon is a small drainage off Eagle Creek and the Big Wood River about 6 miles north of Ketchum, Idaho. The 120-acre burned area is 1.5 miles east of U. S. Highway 93 in the northeast quarter of Section 13, Township 5 North, Range 17 East, Boise Meridian. Since some parts of the area had been heavily disturbed during logging, the specific study site selected for both prefire and postfire examination was a 20-acre patch of less-disturbed terrain on the lower middle slope (fig. 1). The true aspect of this study site is N 10-20° E; the slope is 64 percent, and the elevation is 6,500 feet.

In addition to this specific study site, we established three other subsites within the burn for comparison of postfire vegetal development rates. One of these sites is essentially a replicate of the intensive site, but the other two are higher on the hill in areas that are somewhat steeper, rockier and had considerably fewer trees prior to burning (fig. 2).

In this part of Idaho, summers are cool and winters rigorous. Annual precipitation at the Hailey and Sun Valley weather stations is 14 to 17 inches, most of which falls in the winter. Total snowfall at the two stations averages 85 and 120 inches, respectively. In an average year, maximum temperatures over 90° F. are recorded for only 7 to 15 days while temperatures below 32° F. are recorded for 206 to 288 days. Record minimum temperatures for the respective stations are -36° F. and -46° F. (U. S. Dep. Commerce 1964).

Forested sites in the Sun Valley area are generally confined to north- and east-facing slopes, and vegetation is characterized by abrupt changes associated with aspect, altitude and slope. Douglas-fir *(Pseudotsuga menziesii)*

Figure 2. — Mid-slope and upper slope study sites, Neal Canyon prescribed fire area, July 1963.

is the most important tree species, but lodgepole pine *(Pinus contorta)* is common and subalpine fir *(Abies lasiocarpa)*, Engelmann spruce *(Picea engelmannii)*, and patches of aspen *(Populus tremuloides)* are often associated with mesic microsites. Vegetation beneath the mature forest is highly variable, but is often dominated by Rocky Mountain maple *(Acer glabrum)* and snowberry *(Symphoricarpos oreophilus)* as illustrated in figure 3. On dry south slopes and valley bottoms, vegetation ranges from sagebrush grassland to mixed forb communities.

Soils in Neal Canyon are of both igneous and sedimentary origin although the prescribed burn is confined to an area thinly overlaid with latite and horneblende andesite (Umpleby, Westgate, and Ross 1930). Within the drainage, soils are rocky, poorly developed, and highly stable. Mechanical analyses of representative samples show at least 50 percent gravel and a shift from sandy loams on the surface to a sandy clay loam below 14 inches. Further evidence of soil stability is provided by a sheep driveway in Eagle Creek where overgrazing has caused plant community changes but very little surface erosion.

Wildlife use of Neal Canyon has not been studied in detail although we have observed some evidence of browsing and big game tracks during summer fieldwork. Fifty elk were planted at Ketchum between 1934 and 1936, and the management unit for the Big Wood River supported about 600 elk in 1965 (Tanner 1965). Because of deep snow, Neal Canyon is probably not accessible during the critical winter period, but elk apparently do use the area in the spring and deer probably use it all summer.

Figure 3. — Two views of representative vegetation within the Neal Canyon prescribed fire area, July 1963.

Vegetation Sampling

In the preburn examination of the Neal Canyon forest community, vegetation was divided into five life-form groups:

Trees — over 4.5 feet tall
Subtrees — 1.5 to 4.5 feet tall
Tall shrubs — over 8 feet tall
Low shrubs — 1.5 to 8 feet tall
Herbaceous — all herbaceous vegetation and woody plants under 1.5 feet tall

Herbaceous vegetation and woody plants under 18 inches (including tree seedlings) were recorded in a series of 25 systematically spaced 2- by 2-foot quadrats. Species were listed for each plot, and ground cover was estimated to the nearest square foot. In those cases where a single plant species covered one-fourth or more of the plot, cover data were recorded by species.

Density of woody plants over 18 inches high was estimated using an angle-method[1] version of the quarter-sampling techniques proposed by Cottam and Curtis (1956) and modified by Morisita (1957). From each of 20 points spaced at approximately 50-foot intervals, we measured the distance in each quadrant to the nearest tree, the nearest subtree, the nearest tall shrub, and the nearest low shrub. Distance measurements were corrected to horizontal within the upslope and downslope quadrants.

Trees were categorized by diameter class, and shrub size was determined by measuring two diameters (d_1 d_2) and the height (h) of the plant crown. In subsequent calculations, these measurements were converted to elliptical canopy areas,

$A = \frac{\pi\, d_1\, d_2}{4}$ and to cylindroid volumes, V=Ah.

During the first 2 years following the fire we continued to use quarter-method sampling, but analyses of these data made it apparent that distance techniques were entirely inadequate for the low-density postfire plant community under examination. Despite the 50-foot spacing between sampling points, identical shrubs were sometimes recorded at two or even three consecutive points. Accordingly, in 1966, we located and permanently marked 20, 0.04-acre circular plots on the approximate locations of the quarter-method sampling points. The 2- by 2-foot quadrats were also permanently located and marked with short metal rods.

Because so many shrubs had been recorded at more than one point in the distance measurements, it was possible to plot individual plants by triangulation and create circular-plot data to replace the quarter-method samples of 1964 and 1965. However, the 1963 preburn data included almost no double sampling on the same plants and no attempt was made to replot these data.

Each of the three additional subsites selected in 1966 consists of five circular 0.04-acre plots and ten 2- by 2-foot quadrats. One sample, designated "lower slope" is simply a replicate of the basic 20-point location. The other two sites are located "mid slope" and "upper slope" in the burn where the preburn tree overstory was less dense and the soils are thinner and rockier.

In addition to these permanent plots describing community development, we have established a series of permanent photographic recording points. At least one shrub of each important species, and several representative views of the overall community have been recorded annually in both black and white and color.

Finally, we were fortunate in locating an old wildfire area only a half mile from the Neal Canyon burn and on a virtually identical topographic site. This area, burned in July 1950, has proved to be a valuable aid in predicting successional development on the Neal Canyon burn.

[1] *Mean area per plant* $= \frac{\Sigma \pi r^2}{4N}$ *where r is the distance to the nearest individual in a quadrant, and N is the number of sampling points.*

Figure 4. — Firing the Neal Canyon area, August 1, 1963.

The Fire

Firing of the Neal Canyon site began just after 8:00 a.m., August 1, 1963, and was completed before 5:00 p.m. the same day. Moisture content of fuel-moisture sticks examined at 3:30 p.m. each day during the week preceding the fire had been a relatively constant 5 to 6 percent. During the firing period, air temperatures rose from the mid-50's to nearly 80° F., and the relative humidity dropped from around 50 percent to 10 percent, or less.[2] Surface winds were mostly under 5 m.p.h. during the day, but fire-induced gusts to 30 m.p.h. were recorded during the peak of burning and estimates of wind velocities within the fire were even higher.

Firelines were burned out first, and then the major fire was started by using a flame thrower on a pickup truck driven once across the middle

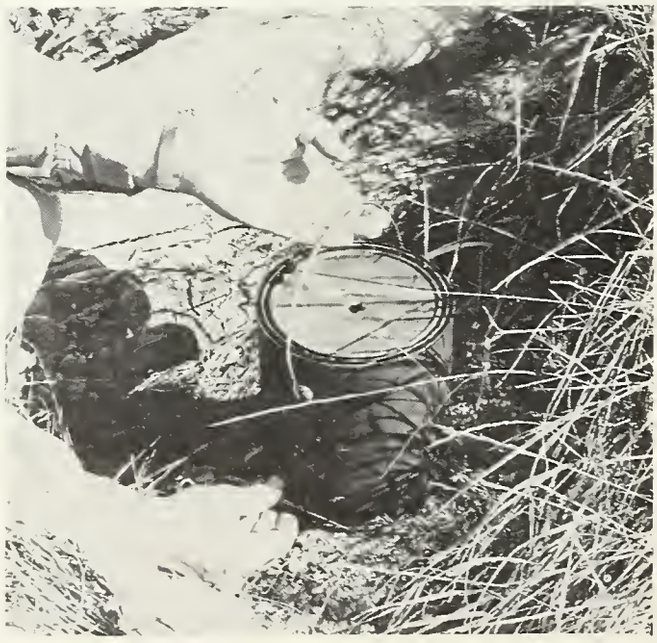

Figure 5. — Water-can heat integrating device.

[2] *Data from U. S. Weather Bureau mobile stations at Eagle Creek and on the hilltop above the fire show generally warmer and drier conditions at the hilltop. These figures represent a broad summary from both stations.*

Figure 6. — Representative photograph within the burned area immediately after the Neal Canyon prescribed fire, August 1, 1963.

of the site and again across the lower edge. The fire swept into the tree crowns almost immediately; and at progressive intervals the entire area was covered by running flame (fig. 4).

Fire intensity was measured with the water-can integrating devices described by Beaufait (1966). These consist of 1-gallon cans painted flat black and containing 3 liters of water at ambient temperature (fig. 5). The weight of water released as steam through a 1-cm. hole in the can lid is a measure of heat absorbed.

Eighteen pairs of these water-can analogs were placed on mineral soil in six evenly spaced vertical lines within the main 20-acre study area. Rolling rocks and logs destroyed 14 cans, but only four of the 18 pairs were lost. Water loss from the remaining 22 cans ranged from 340 to 1,765 grams, with a mean loss of 939.8 grams. Based on calibrations reported by George (1969) this is equivalent to a mean heat energy flux to the surface of the can of 200 calories per second for about 45 minutes. Similar heat flux values have been recorded in broadcast slash fires with 15 to 20 tons of fuel per acre and fine fuel moisture near 5 percent.[3]

Variation in the amount of water evaporated from standard water cans reflected a considerable range in the energy pulse to the site. On site, all the litter and herbaceous material, all dead material less than 3 inches in diameter, and all live stems smaller than 2 inches at the base were completely consumed (fig. 6). Water losses, however, were not clearly related to observed patterns of gross fuel loading (openings, thickets, large shrubs). Apparently, variations in depth of the litter and duff layers were not adequately represented by the occurrence of aerial fuels. Recent studies (Beaufait 1969) have demonstrated that litter and duff shield the can from burning fuels above and that water loss is greatly influenced by the combustion of surface fuels.

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[3] *William R. Beaufait. Unpub. data on file at USDA Forest Serv., Northern Forest Fire Laboratory, Missoula, Montana, 1970.*

Vegetal Succession

Before the Neal Canyon site was burned, the vegetation consisted of 51 plant species, including 6 species of trees and 12 of shrubs. Following the fire, a few species seem to have disappeared, and the relative dominance of important species has been drastically modified. However, one of the interesting modifications shown by the complete listings in the appendix is a substantial increase in number of species during the first 7 years. The tree and shrub component of this forest stand has not changed materially, but the number of species in the herbaceous component has almost doubled. Nevertheless, while the early seral community is considerably richer as to number of species, the mass of biotic production is confined to fewer than a dozen plants. Development of the more important species is summarized in tables 1, 2, 3, and 4.

Patterns of postfire vegetal development in Neal Canyon have been predicated on a hypothetical model of forest succession (fig. 7) in which initial dominance by herbaceous plants is followed with dominance by a shrub community and, in turn, dominance by overstory trees and eventual return to preburn community structure. To date, this model seems adequate even though specific composition of the seral community has demonstrated some very dynamic annual changes.

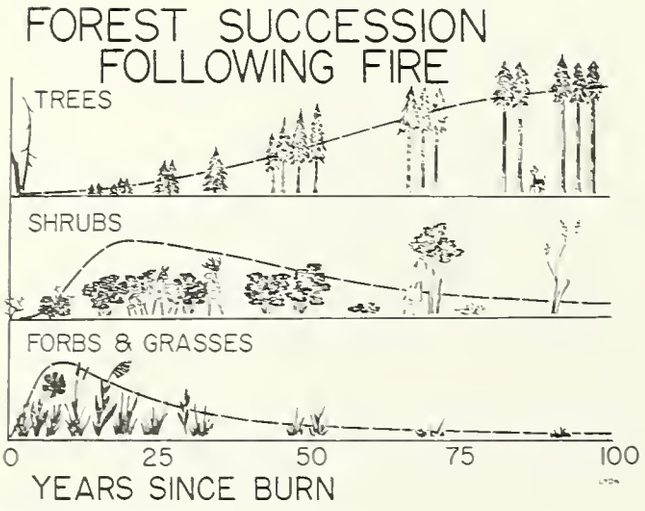


Figure 7. — Hypothetical model of forest succession following fire.

The predicted structure of the community at succession year 20 is suggested by data taken in a 1950 wildlfire area adjacent to the Neal Canyon prescribed burn in 1970 (table 5). There are inherent limitations in this predictive approach because the two burned areas are not exactly alike and because the wildfire area was reforested only by natural seeding. Nevertheless, the similarities between the two sites are so striking that figurative equivalence seems justified in this discussion. The wildfire area is shown in figure 8.

Herbaceous Vegetation

Shortly after the prescribed fire, the new Douglas-fir tree crop was planted and the roads were seeded with a domestic grass mixture. Otherwise, no particular effort was invested in reducing the potential for soil erosion. In this respect, Neal Canyon was a particularly favorable situation because these soils are apparently quite stable even in the absence of vegetal cover. To date, no apparent overland soil movement has been recorded, and the rocks that rolled downhill during the fire probably represent the bulk of surface disturbance on the site.

Nevertheless, it seems significant that herbaceous cover on the Neal Canyon site was almost as dense the first year following the fire as in the preburn community (table 1 and fig. 9). Moreover, while herbaceous cover varied considerably in succeeding years, it never dropped significantly below the preburn level and was, in fact, more than double the preburn percentage in the second year after the fire. This initial surge in herbaceous cover can be almost entirely traced to the development of *Moldavica parviflora*, presumably from residual seed in the duff. One year after the fire, Moldavica was present in 96 percent of the 2-by 2-foot frequency plots and accounted for almost 30 percent of all vegetal cover on the site. When it reached full biennial development in succession year 2, Moldavica covered 37 percent of the total ground surface; and in succession year 3 litter cover jumped to 32 percent due to dead Moldavica stems, leaves, and seed heads.

One obvious question posed by recorded vegetal development concerns the role of Moldavica in shaping successional patterns. The

Table 1. — Percentage cover and frequency of occurrence in 2- by 2-ft. quadrats for abundant herbaceous species and woody species under 18 in. in height, Neal Canyon, 1963-1970

Small-plot data	Pre-burn	Succession year						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
COVER	*Percentage*							
Rock	2	12	6	15	9	10	9	5
Bare ground	4	60	20	21	23	17	15	12
Litter	57	1	5	32	14	17	12	9
Moss and lichen	7	--	--	3	7	12	13	19
Vegetation	30	27	69	29	47	44	51	55
	Frequency of occurrence							
SHRUBS[1]								
Acer glabrum	12	4	x	--	--	--	8	16
Ceanothus velutinus	[2]x	92	92	84	88	92	92	84
Penstemon fruticosus	8	4	24	8	12	16	20	24
Ribes lacustre	20	--	--	--	--	--	--	--
LONG-LIVED PERENNIALS								
Arnica cordifolia	48	24	48	32	36	32	36	40
Aster conspicuus	8	12	20	32	40	40	56	52
Calamagrostis rubescens	24	x	20	28	24	24	24	52
Carex geyeri	52	--	12	20	28	24	24	28
Epilobium angustifolium	20	12	28	48	84	88	88	84
Iliamna rivularis	--	52	36	52	52	56	52	48
Senecio streptanthifolius	44	4	4	4	4	20	32	56
Taraxicum laevigatum	8	x	24	16	40	40	56	68
SHORT-LIVED PERENNIALS								
Cirsium vulgare	12	4	4	16	48	8	36	48
Epilobium watsoni	--	x	48	32	48	12	8	64
Moldavica parviflora	--	96	100	44	100	92	64	76
Phacelia hastata	x	x	20	x	8	4	8	x
ANNUALS								
Bromus tectorum	--	x	4	4	8	4	20	20
Epilobium paniculatum	--	8	88	52	72	20	72	64
Lactuca serriola	--	12	96	32	52	44	20	28

[1] *These data are somewhat misleading because they apply only to seedlings and shrubs under 18 inches in height.*

[2] *"x" indicates species was present in stand but not detected in sample quadrats.*

Table 2. — Density, numbers of plants over 18 in. in height per 1,000 ft.[2]*, Neal Canyon, 1963-1970*

Species	Pre-burn	Succession year						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
Pseudotsuga menziesii	31.4	--	--	T	0.6	0.7	1.2	2.4
Pinus contorta	--	--	--	--	--	T	.2	1.3
Acer glabrum	4.3	1.1	1.1	1.1	1.1	1.5	1.5	1.5
Amelanchier alnifolia	.2	.1	.1	.2	.1	.1	.3	.2
Ceanothus velutinus	.1	--	--	T	.4	11.0	43.4	56.4
Populus tremuloides	--	--	.1	.2	.3	.5	.7	.7
Ribes lacustre	.9	--	--	T	T	--	.3	.1
Ribes viscosissimum	.3	--	--	.8	4.1	9.8	13.3	16.3
Rosa spp.	--	--	--	.1	--	.2	.1	.2
Salix scouleriana[1]	.3	.1	.2	.2	.6	2.4	3.6	4.4
Sambucus racemosa	--	.1	.1	.1	.1	.1	.1	.1
Sorbus scopulina	--	--	--	--	T	T	T	T
Symphoricarpos oreophilus	2.1	--	.3	.6	.7	1.0	1.0	1.1
Other shrubs[2]	--	--	--	.1	.1	.3	.3	.6
Total	39.7	1.4	1.9	3.3	8.2	27.5	66.0	85.3

[1] Salix scouleriana *includes both the 0.14 resprouts per 1,000 feet*[2] *and the seedlings which reached the 18-inch height starting in succession year 3.*

[2] *Includes* Artemisia tridentata, Chrysothamnus nauseosus, Penstemon fruticosa, *and* Shepherdia canadensis.

Table 3. — Estimated total canopy intercept,[1] ft.^{2}/1,000 ft.^{2}, Neal Canyon, 1963-1970

Species	Pre-burn	Succession year						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
	..... *Square feet*							
Pseudotsuga menziesii	[2] 700.0	--	--	--	0.5	0.9	2.2	4.3
Pinus contorta	--	--	--	--	--	T	.1	.8
Acer glabrum	167.1	4.4	13.2	19.4	25.6	33.3	32.9	33.9
Amelanchier alnifolia	2.5	.3	.5	.6	.6	.9	1.2	1.2
Ceanothus velutinus	.2	--	--	.2	1.0	18.3	95.0	99.8
Populus tremuloides	--	--	T	.2	.4	.9	.8	.9
Ribes lacustre	6.7	--	--	T	.1	--	.5	T
Ribes viscosissimum	.6	--	--	.4	4.7	9.7	17.2	15.9
Rosa spp.	--	--	--	.1	--	.2	.1	.2
Salix scouleriana[3]	13.9	2.5	4.4	7.5	12.4	14.6	18.9	21.0
Sambucus racemosa	--	.3	.6	.9	1.4	1.1	.9	.7
Sorbus scopulina	7.0	--	--	--	.2	.3	.4	.4
Symphoricarpos oreophilus	5.8	--	.4	1.7	3.4	4.8	5.1	3.6
Other shrubs[4]	--	--	--	.1	.1	.6	1.1	2.5
Total	903.8	7.5	19.2	31.1	50.4	85.5	176.4	185.0

[1] *These figures can be divided by 10 to produce percentage canopy cover.*

[2] *This estimate taken from aerial photographs.*

[3] *Including only resprouts before succession year 4. Seedlings represent about one-third of the total in succession year 7.*

[4] *Includes* Artemisia tridentata, Chrysothamnus nauseosus, Penstemon fruticosa, *and* Shepherdia canadensis.

Table 4. — Dominance, basal area (in.^{2}) or aerial crown volume (ft.^{3}), plants over 18 in. in height per 1,000 ft.^{2}, Neal Canyon, 1963-1970

Species	Pre-burn	Succession year						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
	Square inches							
Pseudotsuga menziesii	273.0	--	--	--	--	--	T	T
Pinus contorta	--	--	--	--	--	--	--	--
	Cubic feet							
Acer glabrum	1,376.2	6.6	38.6	72.6	113.4	163.5	170.3	187.4
Amelanchier alnifolia	7.9	.5	.9	1.2	1.7	2.5	3.3	2.9
Ceanothus velutinus	.3	--	--	.3	1.7	28.9	171.1	180.3
Populus tremuloides	--	--	.1	.7	1.4	4.0	3.2	3.8
Ribes lacustre	16.8	--	--	.1	.1	--	1.1	T
Ribes viscosissimum	1.0	--	--	.7	7.8	17.2	33.5	31.3
Rosa spp.	--	--	--	.1	--	.3	.3	.3
Salix scouleriana[1]	254.1	12.0	38.9	67.1	111.8	122.4	156.1	190.3
Sambucus racemosa	--	.6	2.3	3.5	6.4	4.6	4.0	3.3
Sorbus scopulina	60.7	--	--	--	.7	1.3	1.8	1.8
Symphoricarpos oreophilus	11.7	--	.7	2.7	6.2	8.8	9.6	7.8
Other shrubs[2]	--	--	--	.1	.2	.9	2.1	4.3
Total (shrubs only)	1,728.7	19.7	81.6	149.0	251.3	354.4	556.5	613.6

[1] *Including only resprouts before succession year 4. Seedlings represent over one-tenth of the total in succession year 7.*

[2] *Includes* Artemisia tridentata, Chrysothamnus nauseosus, Penstemon fruticosa, *and* Shepherdia canadensis.

Table 5. — Density, canopy area (ft.^{2}) and dominance (basal area in.^{2} or volume ft.^{3}), per 1,000 ft.^{2}, 1950 wildfire adjacent to Neal Canyon burn, succession year 20

Species	Density	Canopy area	Basal area or volume
		Square feet	*Square inches*
OVER 18 INCHES IN HEIGHT			
Pseudotsuga menziesii	7.2	108.1	1.5
Picea engelmannii	1.1	30.8	1.0
Populus trichocarpa	.1	.3	T
			Cubic feet
Acer glabrum	.1	.3	.7
Amelanchier alnifolia	.3	1.8	4.8
Artemisia tridentata	1.0	1.2	2.1
Ceanothus velutinus	49.5	656.0	2,000.9
Chrysothamnus nauseosus	.5	.6	1.5
Populus tremuloides	.9	1.0	2.5
Ribes inerme	.2	.6	1.3
Ribes lacustre	2.6	6.0	12.2
Ribes viscosissimum	14.9	30.5	64.8
Salix scouleriana	6.8	42.5	446.1
Symphoricarpos oreophilus	2.3	9.5	20.3
Total	87.5	750.0	2,559.7
UNDER 18 INCHES IN HEIGHT			
Bare ground	--	10	--
Litter	--	380	--
Moss and lichens	--	50	--
Vegetation, including the following:	--	560	--
	Frequency %		
Agropyron spicatum	52	10	--
Arnica cordifolia	52	30	--
Calamagrostis rubescens	32	130	--
Carex geyeri	68	100	--
Carex rossii	60	--	--
Iliamna rivularis	4	--	--
Epilobium angustifolium	36	20	--
Poa nervosa	80	10	--
Potentilla glandulosa	56	10	--
Senecio streptanthifolius	92	20	--
Taraxicum laevigatum	84	--	--
Viola adunca	68	10	--

Figure 8. — This area is adjacent to Neal Canyon prescribed fire and was burned in a July 1950 wildfire (photographed July 1970). Snowbrush predominates on this site.

species is short lived, and despite continuing high frequency values has not made a significant contribution to live cover since succession year 2. There is no way to judge the effect of Moldavica on the ground level microclimate or on the survival of other plant species; however, data from the upper slope site where Moldavica was not present (table 6) suggest that no particular differences were caused. Throughout the burn, and despite considerable variation in slope and the amount of rock surface, vegetal cover has increased from near 30 percent in succession year 3 to 60 percent in succession year 7. Where Moldavica litter was not present, more bare surface was exposed in succession year 2, but cover of herbaceous plants at succession year 7 is surprisingly consistent over the total burned area.

Even though Moldavica completely dominated the initial development of the Neal Canyon vegetation, there was not much evidence for generalization about other short-lived perennials and annuals in forest succession. Recorded frequencies of similar short-lived plants appear to illustrate fluctuations in seed production rather than significant patterns in plant community development. Some of the herbaceous perennials, on the other hand, do appear to develop within sequences which are logical in terms of species autecology and expected position in the mature plant community.

The most obvious sequence of vegetal development is demonstrated by two pioneering species which were not particularly abundant in the preburn community but increased to dominance in the early seral community. By succession year 3, Moldavica was contributing primarily as litter; *Epilobium angustifolium* and *Iliamna rivularis* had become the most

A

E

B

F

C

G

D

H

I

Figure 9. — Prefire (A) and sequential postfire (B through I) vegetation on a representative photo plot. (A) July 1963; (B) August 1963; (C) July 1964; (D) July 1965; (E) July 1966; (F) July 1967; (G) July 1968; (H) July 1969; (I) July 1970.

Table 6. — Percentage cover of herbaceous species and woody species under 18 in. in height, Neal Canyon subsites, 1966-1970

Area	Succession year				
	3	4	5	6	7
	1966	1967	1968	1969	1970
	Percentage				
UPPER SLOPE:					
Rock	40.0	27.5	37.5	22.5	22.5
Bare ground	30.0	32.5	15.0	22.5	15.0
Litter	2.5	0.0	2.5	12.5	2.5
Moss and lichen	0.0	0.0	0.0	0.0	0.0
Vegetation	27.5	40.0	45.0	42.5	60.0
MID SLOPE:					
Rock	20.0	15.0	12.5	12.5	10.0
Bare ground	20.0	15.0	17.5	15.0	17.5
Litter	30.0	17.5	20.0	10.0	10.0
Moss and lichen	0.0	2.5	2.5	5.0	2.5
Vegetation	30.0	50.0	47.5	57.5	60.0
LOWER SLOPE:					
Rock	5.0	5.0	2.5	2.5	5.0
Bare ground	32.5	20.0	25.0	22.5	12.5
Litter	30.0	22.5	20.0	15.0	15.0
Moss and lichen	2.5	7.5	10.0	12.5	17.5
Vegetation	30.0	45.0	42.5	47.5	50.0

important live plants on the burned area. The two species provided about 40 percent of the vegetal cover and about 20 percent of total cover until sucession year 6 when *Ceanothus velutinus* became the dominant species. Predictions for future development suggest that both herbaceous species have already reached a peak and will decrease by succession year 20 (table 5) to frequencies very near those recorded in the preburn community.

Another developmental sequence describes the recovery of some rhizomatous species which were relatively important in the preburn community. Both *Arnica cordifolia* and *Calamagrostis rubescens* appeared in the early seral stand at frequencies only slightly different from those recorded before the fire. Field notes on individual species confirm substantial aggregation rather than random distribution. Frequency data from the 1950 wildfire (table 5) suggest that no major expansion of these species will be recorded although both will probably provide increased cover values as aggregates fill in and then decline somewhat as the shrub stand reaches maturity.

A third sequence of development describes the reestablishment of non-rhizomatous species from the preburn community. *Carex geyeri* and *Senecio streptanthifolius* appeared in the early seral community at frequencies far below preburn levels. During the first 7 years, both species have increased at rates which seem slow but are consistent with the high frequencies expected by succession year 20. In both species, this peak should be followed by a slow decline to the plateau indicated by preburn frequencies.

Despite recorded vegetal resurgence on this burned site, the potential for soil loss created by burning should not be minimized. Before the fire, litter cover was present on over half the soil surface and bryophytes protected another 7 percent. Moreover, overhead canopy in the various tree and shrub layers (table 3) probably approached 100 percent.

By contrast, litter, bryophytes, and tree canopy were all missing in succession year 1, and shrub canopy totaled less than 1 percent. Nearly three-fourths of the surface had no protection until the biennial growth of Moldavica peaked in succession year 2. On a less stable soil, this might have created a significant erosion problem. However, the percentage of surface without vegetal cover (rock and bare ground), has been dropping steadily through succession years 4, 5, 6, and 7 at about 3 to 5 percent each year — a rate consistent with the 1 percent bare ground expected for succession year 20 (table 5).

Woody Vegetation

Prior to burning, the woody plant community in Neal Canyon was dominated by the Douglas-fir overstory. A few large stumps indicated that trees up to 36 inches in diameter had once grown on the site. These very large stems had been removed in two selective timber sales between 1950 and 1960; but there was no evidence either in the form of burned snags or charred material (on the ground) to indicate that the stand had been otherwise disturbed for at least a century. Increment cores from some of the dominant Douglas-firs revealed ages ranging from 28 to 170 years and a cross-section from the largest available willow stem showed 34 annual growth rings.

With the exception of standing snags, this overstory was completely removed by fire, but very few of the woody plants other than trees were actually killed. Most of the shrubs on the site resprouted; but in terms of total vegetal canopy, the woody plants in Neal Canyon contributed much less cover than the herbaceous plants during early succession. However, the projection to succession year 20 (table 5) and the expected return of the preburn mature forest (table 2), both demonstrate the long-term significance of the woody overstory. Moreover, these plants are of particular interest because they provide wildlife habitat values and also represent the eventual timber crop.

Trees: In the first year after the fire, new trees were established on the burned site by three different methods. In one part of the burn, the Ketchum Ranger District planted Douglas-fir stock from the Forest Service Nursery at Savenac, Montana. This stock has done exceptionally well, and by the sixth growing season was well established and healthy (fig. 10). In other parts of the burn, Douglas-fir was direct seeded, and there has been some natural seeding of both Douglas-fir and lodgepole pine.

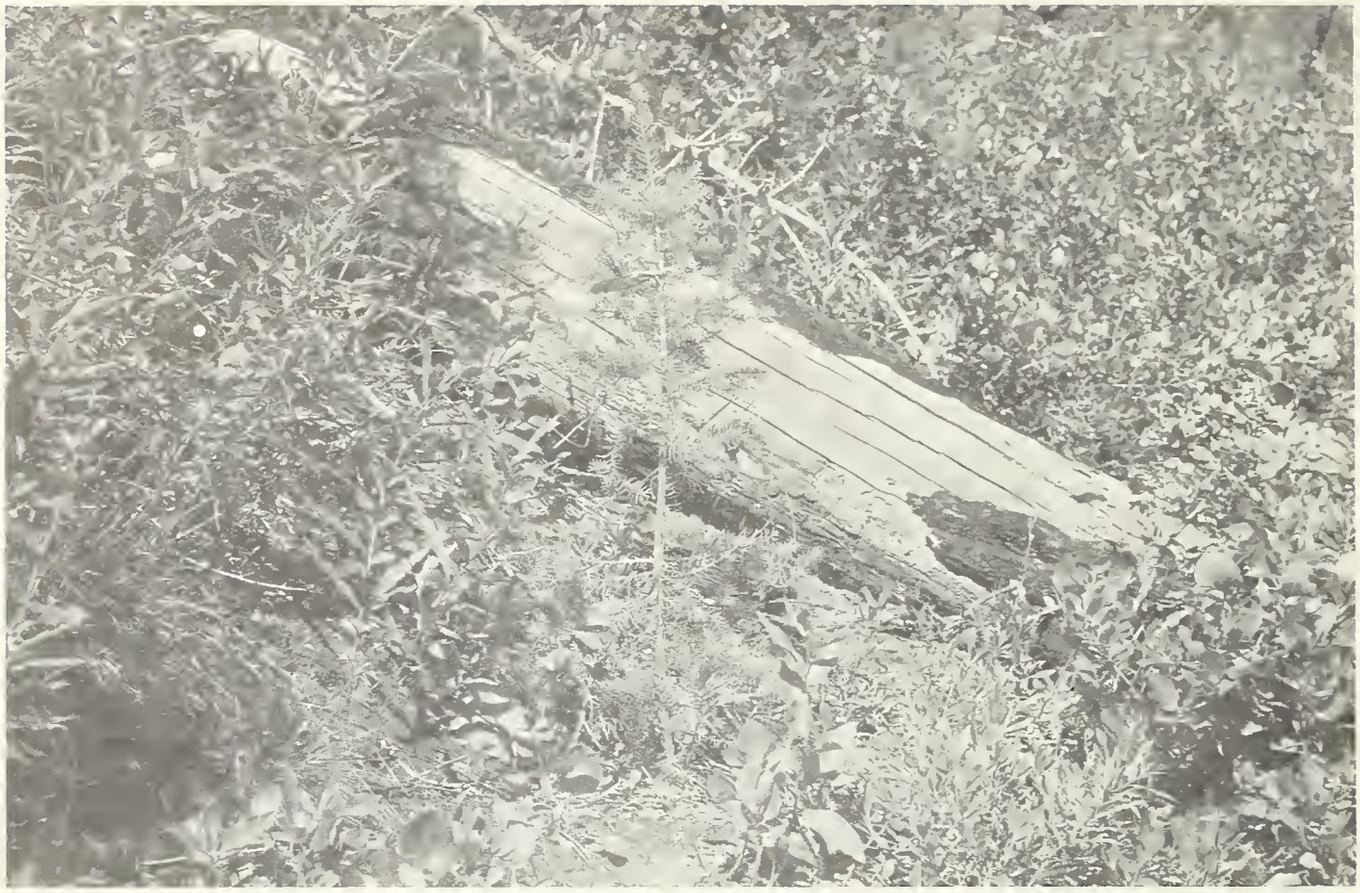


Figure 10. — Seventh year Douglas-fir in Neal Canyon plantation.

On the main Neal Canyon study site, the first five 0.04-acre plots extend through a plantation in which 45 Douglas-firs over 18 inches high were recorded. In addition, these 5 plots contain 24 lodgepole pines. The remaining 15 plots, and the additional 15 subsite plots, contain 58 more Douglas-firs and 19 lodgepole pines. Finally, 7 Douglas-fir seedlings and a whitebark pine *(Pinus albicaulis)* were recorded in the 2- by 2-foot plots. These data are obviously inadequate to establish survival and stocking rates for the Neal Canyon burned area, but the indicated density for trees is certainly higher than the density recorded in the 20-year stand. Depending on seedling survival and further interseeding, the probable tree density can be estimated at somewhere between 9 and 27 stems per thousand square feet (400-1,200 stems per acre).

Prediction of the date of crown closure is, of course, purely conjectural on the basis of the inadequate sample available at this time. However, projection of the crown-width on stem diameter regression presented by Smith, Ker, and Csizmazia (1961) shows that 1,200 Douglas-fir, evenly spaced, would reach canopy closure at a d.b.h. of 1 inch. Slightly over 400 per acre, evenly spaced, would reach canopy closure at 4 inches d.b.h. Presuming moderately good growing conditions, Douglas-fir on the Neal Canyon site could reach a d.b.h. of 4 inches in about the thirtieth year of succession.

Shrubs: As of succession year 4, total numbers of shrubs over 18 inches tall were about the same as recorded before the fire. However, by succession year 7, shrub density had increased tenfold. Canopy intercept, on the other hand, had not reached the preburn level and crown volume in succession year 7 was just over one-third of the preburn volume. Projection of shrub canopy to succession year 20, as suggested by table 5, indicates a continuing in-

crease with shrub canopy equaling the herbaceous cover percentage sometime between succession years 10 and 15.

Within the shrub community, there were some substantial shifts in dominance among various species. In the preburn community, mountain maple accounted for more than half of shrub density, over 80 percent of the shrub intercept and nearly 80 percent of the shrub crown volume. During the first 2 years of succession, comparative densities remained fairly close to 10 maples for each Scouler willow *(Salix scouleriana)*, but because willow resprouted so much more vigorously, canopy intercept of maple was only slightly greater and crown volume of willow was greater than that for maple.

In succession year 3, total volumes of both species were about equal; and by succession year 5, maple was again the dominant shrub species. However, in succession year 6, crown volume of snowbrush reached about the same level as maple and willow; and straight-line projections to estimates for succession year 20 (table 5) suggest that the volume of snowbrush will exceed the combined volumes of all other shrubs after succession year 9. This dominance will very likely be maintained through most of the next 30 to 50 years or until the developing trees overtop and shade the snowbrush.

Changes among other shrub species are somewhat less spectacular, but the effects of fire are certainly evident in several ways. The two Ribes species, for example, have reversed relative importance as a result of the fire. Sticky currant was infrequent in the preburn community, but following the fire, many new plants have appeared and the species has made a substantial contribution to shrub canopy and volume since about succession year 4. Projection to succession year 20 suggests continuing importance for a number of years.

Meanwhile, prickly currant has virtually disappeared from the main site of investigation. The only plants recorded constitute such a small sample that the species has no apparent role in community structure. Data from other sites within the burn (table 7) show that this is not just a peculiarity of the one site. In every area sampled, *R. viscossissimum* is substantially more dense than *R. lacustre*. Projections to succession year 20 suggest a slow increase requiring as much as 30 to 40 years to regain preburn crown volumes.

Shrub Growth Rates: Although the shrub contribution to total vegetal cover is not expected to equal the herbaceous contribution until succession year 10, the management significance of these woody plants is relatively high. Forage and cover for game animals are produced by many shrub species, and one of the significant questions of habitat manipulation concerns the speed at which shrub recovery takes place. One expression of growth is supplied by the community-structure summary (tables 2-4). However, these summary data do not provide an unbiased expression of growth rates because they include both the increases in plant size and apparent increases in density as smaller plants surpass the artificial 18-inch height limit of our sampling method. Also, when cover values or forage values are considered, the average size of all plants is probably somewhat less important than the average for those larger plants which will protrude through the snow and, presumably, be the longest lived in any eventual competition for light and moisture.

Accordingly, samples including 4 to 31 plants of 6 species which contribute over 95 percent of shrub volume have been selected for an individual growth-rate study. These samples include those plants of each species first to exceed the sampling height limit of 18 inches. They are not marked on the study site as individual plants, but no more than six of any one species are included in a single 0.04-acre plot and it is generally possible to identify these larger specimens on a year-to-year basis in the data.

Because these samples are quite small, crown volume and height means presented in table 8 must be interpreted with discretion. Data on snowberry, for example, show a 1970 mean size of 19.0 $ft.^3$, but this represents a range from 6.9 $ft.^3$ for nine plants on the main study site to 25.8 $ft.^3$ for 15 plants on the upper slope. Despite the small samples, however, it is possible to make some general comparisons among the resprouting and growth rates of the six species listed.

Tall shrubs. — Plants that resprout on a

Table 7. — Density and aerial crown volume for species over 18 in. in height and more than one ft.^{3} per 1,000 ft.^{2}, Neal Canyon subsites, 1966-1970

Area	1966	1967	1968	1969	1970	1966	1967	1968	1969	1970
	..... Number of plants					..... Crown volume ft.^{3}				
UPPER SLOPE:										
Acer glabrum	0.9	0.6	1.5	1.4	1.3	26.1	38.6	90.0	104.5	77.3
Artemisia tridentata	--	.1	--	.1	.2	--	.1	--	.2	1.1
Ribes lacustre	.1	.5	.2	.2	.5	.7	2.0	1.4	1.8	2.5
Ribes viscosissimum	.1	--	.7	.8	2.4	.1	--	.7	1.4	5.8
Symphoricarpos oreophilus	9.4	9.3	11.2	10.9	10.3	79.0	104.3	132.3	136.1	125.0
Totals	10.5	10.5	13.6	13.4	14.7	105.9	145.0	224.4	244.0	211.7
MID SLOPE:										
Acer glabrum	.2	.2	.3	.3	.3	.3	1.8	4.2	5.9	10.4
Amelanchier alnifolia	.2	.3	.9	.8	.6	3.1	10.2	14.9	13.3	21.0
Ceanothus velutinus	--	.1	1.5	8.0	11.1	--	.1	5.0	33.9	46.9
Ribes viscosissimum	.1	.2	.8	1.0	2.5	.1	.7	1.9	3.7	6.5
Rosa spp.	.3	.1	.2	.1	.1	.3	.5	.8	1.0	.4
Symphoricarpos oreophilus	1.5	1.8	3.7	3.3	2.6	9.6	16.2	28.8	30.8	27.2
Totals	2.3	2.7	7.4	13.5	17.2	13.4	29.5	55.6	88.6	112.4
LOWER SLOPE:										
Acer glabrum	.1	.1	.1	.1	.1	2.0	3.8	3.8	3.8	4.1
Amelanchier alnifolia	.3	.3	.5	.5	.5	3.7	1.5	4.9	6.3	4.8
Artemisia tridentata	--	.1	.1	.3	.1	--	.4	.5	1.2	.3
Ceanothus velutinus	--	--	13.3	21.8	33.4	--	--	45.7	96.4	125.0
Populus tremuloides	.2	.2	1.0	.6	1.1	.2	.3	1.5	2.0	--
Ribes lacustre	.2	.2	1.0	1.3	1.8	.2	.4	2.6	7.4	4.4
Ribes viscosissimum	4.9	8.4	21.9	21.3	28.1	4.5	21.6	51.0	61.6	72.5
Salix scouleriana	1.4	1.5	3.3	4.4	5.9	189.9	200.7	253.8	609.2	721.4
Sorbus scopulina	--	.1	.2	.1	--	--	.5	1.0	2.0	--
Symphoricarpos oreophilus	.3	.2	.3	.2	.5	1.6	1.4	1.8	2.0	2.9
Totals	7.4	11.1	41.7	50.6	71.5	202.1	230.6	366.6	791.9	935.4

Table 8. — Average height and volume ($ft.^3$) for a selected sample of shrubs, Neal Canyon, 1963-1970

Species	Sample size	Succession year						
		1	2	3	4	5	6	7
		1964	1965	1966	1967	1968	1969	1970
		Average height (ft.)						
Salix scouleriana	6	5.1	8.0	8.3	8.5	8.8	9.7	10.5
Acer glabrum	17	1.8	3.0	3.6	4.4	5.0	5.4	5.8
Symphoricarpos oreophilus	31	--	--	1.7	1.9	1.9	2.1	1.9
Ceanothus velutinus	14	--	--	--	1.5	1.9	2.2	2.4
Ribes lacustre	4	--	--	1.7	1.6	1.5	2.4	1.9
Ribes viscosissimum	26	--	--	1.6	2.0	2.0	2.5	2.5
		Average volume ($ft.^3$)						
Salix scouleriana	6	82.7	231.6	462.1	760.1	812.5	978.9	991.8
Acer glabrum	17	5.8	46.0	75.3	126.3	157.3	173.3	202.1
Symphoricarpos oreophilus	31	--	--	11.9	16.6	20.1	23.1	19.0
Ceanothus velutinus	14	--	--	--	2.7	6.9	15.5	19.3
Ribes lacustre	4	--	--	2.6	3.1	4.4	11.5	6.2
Ribes viscosissimum	26	--	--	1.4	4.4	5.7	8.5	7.2

Table 9. — Decline in number of snowbrush plants, 1964-1970, Neal Canyon prescribed burn area per 1,000 $ft.^2$

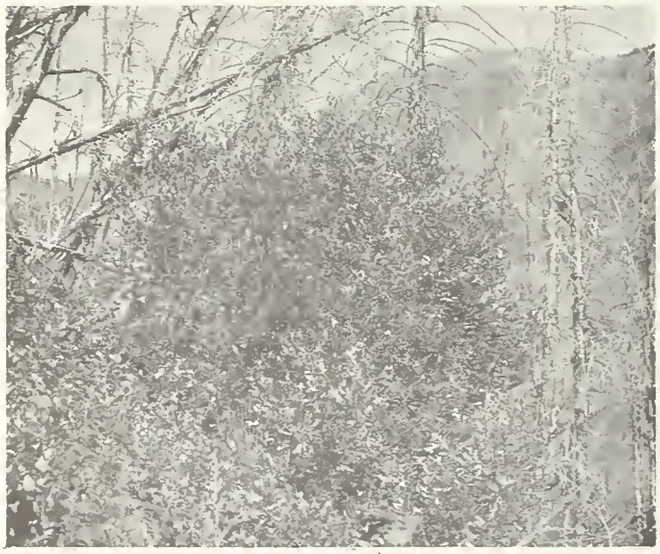
	Succession year						
	1	2	3	4	5	6	7
	1964	1965	1966	1967	1968	1969	1970
Seedlings (<18 in. tall)	4,460	2,610	2,130	1,750	1,490	1,160	740
Plants (>18 in. tall)	--	--	T	0.4	11.0	43.4	56.4
Total *Ceanothus velutinus*	4,460	2,610	2,130	1,750.4	1,501.0	1,203.4	796.4

burned-over site provide two values for wildlife. The first, and most obvious, is production of forage at a height within reach of animals. To some degree, however, the use of this forage may be limited by the lack of natural escape cover. Thus, a shrub that furnishes both food and cover could be somewhat more valuable than one which furnishes only forage.

Among the species present on the Neal Canyon site, only the willow and mountain maple seem likely to be dense enough and tall enough to provide cover for big game animals before the trees fulfill this role. Adequate cover for grouse and small mammals is probably supplied

(1 year)

(3 years)



(7 years)

Figure 11. — Resprouting Scouler willow (S. scouleriana), *1, 3, and 7 years after the Neal Canyon prescribed fire.*

(1 year)

(3 years)

(7 years)

Figure 12. — Resprouting mountain maple (A. glabrum), *1, 3, and 7 years after the Neal Canyon prescribed fire.*

by all the woody species and some of the herbaceous plants. For small animals, however, density of cover is probably more significant than height.

Measurements of resprouting and growth of willow in Neal Canyon provide a most convincing demonstration of plant recovery following crown-kill by fire (fig. 11). Resprouting willows were over 5 feet tall in the first year and the average plant volume equaled the preburn average by the fourth growing season. However, nearly 80 percent of the height growth for 7 years was achieved in the first two growing seasons, and continuing expansion has been along horizontal planes.

Considering the recorded rate of height growth, willow was at least partially out of reach for game animals by the second growing season. However, it appears that prefire willow heights ranging up to 27 feet will not be achieved until these plants are forced into competition with overstory trees.

Growth patterns of mountain maple were much different than those of willow (table 8 and fig. 12). Height growth in the first 2 years only produced 52 percent of the 7 year height and both the height and volume increments have been relatively constant from year-to-year throughout the study. The maple, obviously, did not contribute much to cover requirements of big game on this site until possibly the third year of regrowth. On the other hand, forage produced has yet to grow completely out of reach and it is apparent that maple can make a substantial contribution to forage balance on a range which has enough willow to provide adequate cover.

Low shrubs. — The low shrub specimens listed in table 8 probably represent both seedlings and resprouts. Densities of sticky currant and snowbrush in particular, have increased substantially above preburn densities in the 7 years since the fire. It is also of interest that all species except prickly currant are represented by plants substantially larger than the mature plants of the preburn community. Snowberry, for example, has an average canopy area of 10 $ft.^2$ for these larger plants as compared to less than 3 $ft.^2$ for mature plants in 1963 (fig. 13).

All species except snowbrush showed a drop in height and volume from 1969 to 1970. This

(1 year)

(3 years)

(7 years)

Figure 13. — Resprouting snowberry (S. oreophilus), *1, 3, and 7 years after the Neal Canyon prescribed fire.*

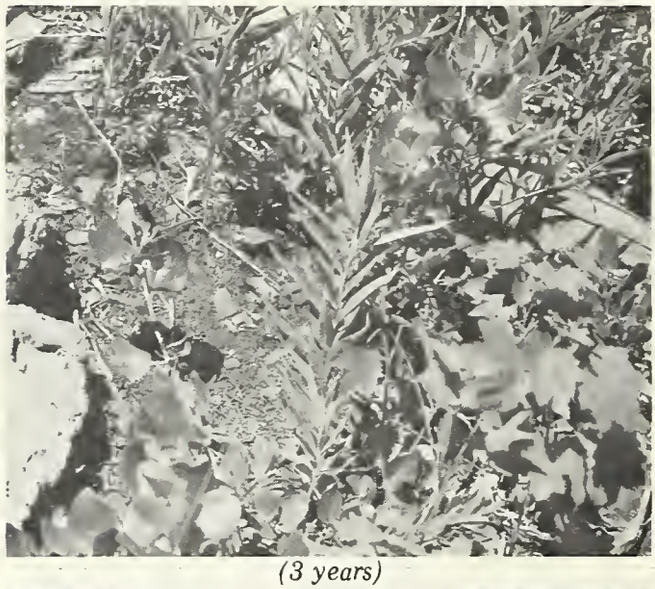
is interpreted as the effect of heavy winter snow, but it also suggests that sticky currant and snowberry may have reached the potential in size development which can be expected on this site. When the overstory of trees finally provides some protection from snow, shade is expected to cause a reduction in average size to preburn levels for these two species. In the case of prickly currant, however, optimum environmental conditions will not occur until overstory trees produce shade. Thus, snow is expected to be somewhat limiting during the treeless period, but as soon as site conditions are adequately modified this species should respond vigorously.

From the wildlife standpoint, snowberry and the two currants are relatively unimportant in this stand. All are moderately palatable to big game and the currants may supply some fruit for smaller animals, but in the presence of the existing variety of highly palatable shrubs, the forage contribution of these species will be small.

Snowbrush, on the other hand, is generally considered to have high palatability, and when available in the amounts present on this site must be considered a significant forage resource. Moreover, it is a forage resource directly resulting from the use of fire as a management tool. Gratkowski (1962) has shown that snowbrush seeds can lie in the duff of a mature timber stand for periods ranging up to 300 years. Then, following fire in the forest and a period of cold stratification, dormancy is broken and the accumulated seed production of 30 to 50 years germinates on the burned area.

In the Neal Canyon study, our samples for 1964 showed more than 4,000 snowbrush seedlings per 1,000 ft.^{2} of surface (nearly 200,000 per acre). Over 40 percent of these plants had died by succession year 2, and in succession year 7 less than one fifth of the original plants were still alive (table 9). Of these, only 7 percent are over 18 inches in height (fig. 14), and yet, they contribute over 50 percent of the shrub cover (table 3). Based on the prediction to succession year 20 (table 5), snowbrush density will eventually be reduced to about 50 plants per 1,000 ft.^{2} with a canopy area approaching 70 percent.

(1 year)



(3 years)

(7 years)

Figure 14. — Snowbrush (C. velutinus) *seedlings at 1 year and representative plants 3 and 7 years after the Neal Canyon prescribed fire.*

DISCUSSION

Prescribed fire has advantages in certain situations and limitations in others. One of the major limitations is that potential results of prescribed fires are not well understood and the disadvantages can easily be overemphasized. Data obtained from the prescribed burn in Neal Canyon will not resolve the problems of fire management, but this burn does demonstrate that there are situations in which virtually all of the results can be considered favorable.

The Neal Canyon prescribed fire was conducted in August under extreme conditions. Yet, the recorded heat flux was within ranges obtained in slash disposal fires on logged sites in the northern Rocky Mountains and the fire was not lethal to any significant proportion of the plant species that had resprouting capabilities. The heat flux to soil surface and vegetation obtained in the Neal Canyon prescribed fire can be duplicated following logging in situations similar to the one recorded here. However, Shearer and Hammer[4] have found that soil moisture is generally higher and heat penetration less under slash than in adjacent undisturbed forest stands. Until these factors are fully evaluated, duplication of the biological results obtained in Neal Canyon may be limited to similar ecological situations in standing timber.

The postfire resurgence of both herbaceous and shrub cover indicate the potential value of prescribed fire in managing vegetation for the benefit of wildlife. The preburn forest community on the Neal Canyon site contributed very little forage for big game. Within 1 year after burning, resprouts of tall shrubs had become available to animals, and the initial development of a substantial browse field was evident in the germinating snowbrush. Finally, although the study was not specifically designed to evaluate silvicultural success or soil movement and watershed effects, both the planted and direct-seeded trees appear adequate and there is no evidence that burning caused watershed damage.

Prediction of Results

One of the most noteworthy ecological comparisons in the Neal Canyon study is the relative similarity of preburn and postburn forest communities. New plant species did appear following the fire, particularly in the herbaceous category. However, the major constituents of the postburn community were represented in the preburn forest stand. Because they were so represented, it is reasonable to assume that appropriate preburn sampling can be used to predict postfire cover patterns for forest communities other than the one described here.

An example of the form such predictions might take is illustrated in figure 15. Following the hypothetical model of figure 7, data from the preburn sample and the first 7 postfire years (tables 1 and 4) are shown as actually recorded. Data from the 20-year-old burn (table 5) were extremely helpful but not absolutely necessary as a guideline in determining the probable course of various curves. Beyond 20 years, all curves have been smoothed to expected values near the preburn level in about

[4] *Raymond C. Shearer and Robert G. Hammer. Soil moisture, soil temperature and root mortality associated with prescribed burning on western larch forests. Intermountain Forest and Range Exp. Station, Ogden, Utah. (Manuscript in preparation)*

the fiftieth year. Development rate curves are already available for many tree species but much more work is needed to verify the reactions and development rates of shrubs and herbaceous cover on other sites. However, even the limited information available in a pretreatment sample would provide an empirical base for estimating shrub curves.

If the model of figure 15 were combined with similar models for other sites, long-term patterns of both forage and cover availability could be predicted for areas as large as herd-management units or Ranger Districts. Such predictions would be of significant value in integrating wildlife management with other resource management disciplines. Toward this objective, a computer program designed to integrate winter-range forage production estimates on large areas has already been developed by Region 1 of the U. S. Forest Service (Giles and Snyder 1970). Further refinements will be required to incorporate summer ranges and cover values, but the potential for improving current habitat management practices and stabilizing big game herd levels appears to be substantial.

In the present state of the art, the Neal Canyon prescribed burn may be most useful in supplying a specific logic for the manipulation of vegetation on small areas for the benefit of wildlife. Where preliminary sampling indicates a potential for the development of a big game forage resource with fire or logging, the predicted composition of the postburn community can be used as a guideline in determining the size of the desired opening and the requirements for juxtaposition of other vegetal types. Figure 15, for example, shows a substantial forage resource within 2 years after the Neal Canyon burn; but the cover within the burned area was relatively poor until the mountain maple began to reach a height of 4 to 5 feet. On some sites, the absence of tall shrub species might prolong the cover-free period 10 to 15 years until trees reach a height which will encourage access for animals. This could be particularly important on a white-tailed deer range and would logically lead to the creation of smaller openings or the provision of uncut stringers of trees to encourage utilization of the newly created forage resource.

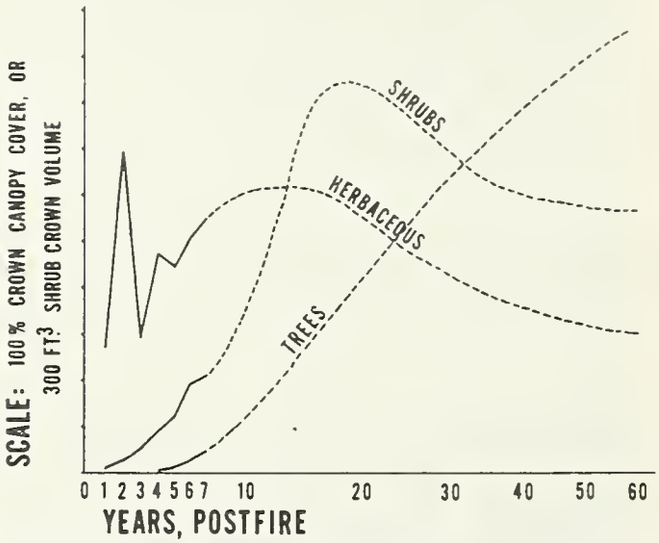

SCALE: 100% CROWN CANOPY COVER, OR
300 FT.³ SHRUB CROWN VOLUME
SHRUBS
HERBACEOUS
TREES
0 1 2 3 4 5 6 7 10 20 30 40 50 60
YEARS, POSTFIRE

Figure 15. — Theoretical development of Neal Canyon vegetal community.

Conclusions

In summary, the prescribed fire on the Neal Canyon site can be considered an exceptional success in virtually every respect. Timber management objectives were achieved, wildlife habitat was markedly improved, and watershed protection was not compromised. Moreover, the fire provides a basis for predictions of the effects of similar fires on other sites. However, it cannot be too strongly emphasized that fire can also produce vastly different results in other ecological situations. Areas with depauperate vegetal communities and fragile soils do not recover from burning in the relatively short time periods suggested at Neal Canyon. Some areas, in fact, may never recover if subjected to repeated fire as a treatment practice. Fire can be useful as a management tool only when we can predict and fully understand the results it will produce in specific locations. The Neal Canyon fire provides one step toward this understanding.

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APPENDIX

PLANT SPECIES PRESENT ON NEAL CANYON PRESCRIBED FIRE SITE, 1963-1970[1]

(Nomenclature follows Hitchcock et al., 1955-1969[2])

Species	Pre-burn	Succession years						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
TREES								
Abies lasiocarpa	x	--	--	--	--	--	--	--
Picea engelmannii	x	--	--	--	--	--	--	--
Pinus albicaulis	x	--	--	--	--	--	--	x
Pinus contorta	x	--	--	4	4	4	4	x
Populus tremuloides	x	--	x	x	x	x	x	x
Pseudotsuga menziesii	20	20	4	16	16	16	16	24
SHRUBS								
Acer glabrum	12	4	x	x	x	x	8	8
Amelanchier alnifolia	x	x	x	x	x	x	x	x
Artemisia tridentata	x	x	--	--	x	x	x	x
Ceanothus velutinus	x	92	92	84	88	96	92	84
Chrysothamnus nauseosus	--	x	--	x	x	x	4	x
Chrysothamnus viscidiflorus	--	--	--	--	--	x	x	x
Cornus stolonifera	x	--	--	--	--	--	--	--
Haplopappus macronema[3]	--	--	--	--	--	x	--	--
Penstemon fruticosus	8	4	24	8	12	16	20	24
Ribes lacustre	20	--	x	x	x	x	x	4
Ribes viscosissimum	4	24	44	20	28	24	20	20
Rosa woodsii[3]	--	--	--	--	x	--	x	x
Salix scouleriana[3]	x	x	x	x	x	x	x	x
Sambucus racemosa	x	x	x	x	x	x	x	x
Shepherdia canadensis	--	--	--	--	x	x	x	x
Sorbus scopulina	x	--	--	x	x	x	x	x
Symphoricarpos oreophilus	12	x	x	x	x	4	4	4
HERBACEOUS AND LOW WOODY PERENNIALS								
Achillea millefolium	--	--	--	x	x	x	x	8
*Agropyron cristatum**	--	--	--	x	x	x	x	x
Agropyron spicatum	8	--	--	4	4	8	12	16
*Agropyron trichophorum**	--	--	--	--	--	--	--	4
Antennaria rosea	x	--	--	--	--	x	4	8
Arnica cordifolia	48	24	48	32	36	32	36	40
Aster campestris[3]	--	--	--	--	--	--	x	x

(continued)

Species	Pre-burn	Succession years						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
Aster conspicuus	8	12	20	32	40	40	56	52
Aster foliaceus	--	--	--	--	x	4	4	8
Berberis repens	x	4	--	--	--	--	--	--
*Bromus inermis**	--	--	--	12	8	12	24	16
Calamagrostis rubescens	24	x	20	28	24	24	64	52
Carex geyeri	52	12	12	20	28	24	24	20
Carex rossii	--	--	12	28	28	28	28	36
Castilleja miniata	8	--	--	--	--	x	x	4
*Cirsium arvense**	--	--	--	--	--	x	x	x
Clematis columbiana	4	x	x	--	--	x	x	x
Epilobium angustifolium	20	12	28	48	84	88	88	84
Galium triflorum[3]	x	--	--	--	--	--	--	--
Heuchera parviflora[3]	x	--	--	--	--	--	--	--
*Hordeum jubatum**	--	--	--	--	--	--	x	--
Iliamna rivularis	--	52	36	52	52	56	52	48
Lithospermum ruderale	x	--	x	--	--	--	--	x
*Lolium multiflorum**	--	--	--	x	--	--	--	--
Lomatium triternatum	--	--	--	--	--	--	x	--
Melica bulbosa[3]	--	--	--	x	--	--	--	--
Osmorhiza chilensis[3]	x	--	--	--	--	--	--	x
Penstemon attenuatus	--	--	--	--	--	--	--	x
Poa nervosa	20	--	--	x	x	4	4	16
Potentilla arguta[4]	20	--	x	--	x	x	16	8
Potentilla gracilis	x	--	--	--	--	--	--	--
Pyrola secunda	12	--	--	8	12	8	8	4
Pyrola virens	x	--	--	--	--	--	--	--
Senecio serra	--	--	--	x	--	4	8	x
Senecio streptanthifolius	44	4	4	4	4	20	32	56
Sitanion hystrix	--	--	--	--	--	--	--	4
Smilacina racemosa	x	x	4	--	--	--	--	--
Taraxacum laevigatum[5] *	8	4	24	16	40	40	56	68
Trisetum spicatum	12	--	--	x	--	--	--	x
Valeriana acutiloba[3]	x	--	--	--	--	--	--	x
Viola adunca	12	8	12	--	--	x	x	8
BIENNIALS AND SHORT-LIVED PERENNIALS								
Arabis drummondii[6]	x	--	x	x	x	x	x	4
Arabis holboellii	4	--	--	x	12	8	24	20
Chaenactis douglasii[3]	--	--	--	--	--	--	x	x
Cirsium canovirens	--	--	--	--	--	x	x	8
*Cirsium vulgare**	12	4	4	16	48	40	36	48

(continued)

Species	Pre-burn	Succession years						
		1	2	3	4	5	6	7
	1963	1964	1965	1966	1967	1968	1969	1970
Corydalis aurea	--	4	4	--	--	--	--	--
Epilobium watsonii	--	x	48	32	48	12	8	56
Erigeron acris	--	--	--	--	--	4	4	4
Frasera speciosa	16	--	4	--	--	x	x	x
Machaeranthera canescens	--	--	--	--	--	x	x	8
Moldavica parviflora	--	96	100	44	100	92	64	76
Phacelia hastata	x	8	20	x	8	4	8	x
*Potentilla biennis**	--	--	--	--	--	--	--	x
*Tragopogon dubius**	--	x	24	8	24	40	36	28
*Verbascum thapsus**	--	--	4	--	--	16	20	28
ANNUALS								
*Bromus tectorum**	--	4	4	4	8	4	20	20
*Capsella bursa-pastoris**	--	x	x	--	4	--	--	4
*Chenopodium album**	--	--	--	x	4	x	x	x
Collinsia parviflora	8	x	8	4	12	8	20	12
Collomia grandiflora	--	--	--	4	12	8	16	16
*Conzya canadensis**	--	x	--	--	--	--	--	--
Cryptantha affinis	4	x	4	x	8	20	8	12
Descurainia richardsonii	x	x	x	--	--	x	4	4
Epilobium paniculatum	--	8	88	52	72	80	72	64
Galium aparine	--	--	--	--	--	--	--	x
Gayophytum nuttallii	--	--	--	x	4	x	x	4
Geranium bicknellii[3]	--	x	--	--	--	--	--	--
*Lactuca serriola**	--	12	96	32	52	44	20	28
Lepidium virginicum	--	--	--	--	--	x	x	--
Madia glomerata	--	--	--	--	--	--	--	x
*Myosotis micrantha**	--	--	--	--	--	--	--	4
Polygonum douglasii	--	--	--	--	x	x	4	x
*Sisymbrium altissimum**	--	--	--	--	--	--	--	x
*Spergularia rubra**	--	--	4	--	--	--	--	--
*Triticum aestivum**	--	x	8	--	--	--	--	--

[1] *"x" indicates species was present in stand but not detected in sample quadrats. Numerical designations are percentage frequency of occurrence in twenty-five 2- by 2-foot quadrats.*

[2] *C. Leo Hitchcock, Arthur Cronquist, Marion Ownbey, and J. W. Thompson, Vascular Plants of the Pacific Northwest. Seattle: Univ. Wash. Press (5 parts, 2,978 p.) 1955-1969.*

[3] *Tentative identification pending collection of flowering material.*

[4] *Includes* P. glandulosa.

[5] *May include* T. officinale.

[6] *May include* A. glabra.

**Introduced species.*

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